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Title of Invention: projection exposure device

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Specification

1. Title of Invention: Projection exposure device

2. Scope of Claims:

(1)

A projection exposure device that projects and exposes a pattern on a reticule onto a wafer through a projection optical system, said device comprising a special stop by which the distribution of intensity on the exit plane of a secondary light source which illuminates said reticule is made larger toward the periphery than at the center.

(2)

The projection exposure device of claim 1, wherein the special stop can be mounted immediately behind the secondary light source plane, with the shape of the aperture and the distribution of the transmissivity being so made that the intensity of light at the periphery is higher than the intensity of light at the center.

(3)

The projection exposure device that projects and exposes a pattern on a reticule onto a wafer through a projection optical system, said device comprising a special stop by which the distribution of intensity on the exit surface of a secondary light source which illuminates said reticule is made larger toward the periphery than at the center and a uniform stop that does not have any effect on the distribution of intensity on the exit surface of the secondary light source, said stops being interchangeable.

(4)

The projection exposure device of claim 3, wherein the special stop and the uniform stop can be mounted immediately behind the secondary light source plane.

(5)

The projection exposure device of claim 4, wherein the secondary light source has, in the front, a conical lens that enables the light intensity distribution, of light rays incident on a homogenizing optical system for forming the secondary light source, to make similar to resemble the distribution of transmissivity and shape of the aperture of the stop provided immediately behind the secondary light source plane.

3. Detailed Description of the Invention

[Industrial applications]

The present invention relates to a projection and exposure device that forms a fine resist pattern necessary for producing semiconductor integrated circuits and the like.

[Description of Prior Art]

Figure 5 shows one type of conventional projection and exposure device. In figure 5, reference number 1 designates a lamp, reference number 2 designates elliptical reflecting mirrors, reference number 3 designates the second focal point of elliptical reflecting mirrors 2, reference number 4 designates an input lens, reference number 5 designates an optical integrator, reference number 6 designates an output lens, reference number 7 designates a collimation lens, reference number 8 designates a reticule, reference number 9 designates an aperture stop as a uniform stop, reference number 10 designates a filter, reference numbers 11 and 12 designate cold mirrors (NOTE: diathermic mirrors), reference number 13 designates a lamp housing, reference number 14 designates a projection optical system that projects the image of the pattern on reticule 8 onto a wafer by means of a lens or a mirror or a combination thereof, reference number 15 designates a wafer, and reference number 16 designates an aperture stop.

Conventionally, many of this kind of projection and exposure devices use mercury lamps as lamp 1 of the light source, and use bright lines such as the 436 nm g-line, the 405 nm h-line and the 365 nm i-line, or the continuous spectra in the area of these wavelengths. Consequently, it is necessary for lamp 1 of the light source to have high luminance, and it is preferable for the lamp to be nearly a point light source in consideration of illumination uniformity and light condensing efficiency. However, because in practice this kind of ideal light source does not exist, it is necessary to use a lamp 1 having a distribution of intensity of finite size. Thus the concern is converting with high efficiency the light emitted from this kind of lamp 1 into light with good illumination uniformity.

The device shown in figure 5 is a device having a structure using a conventional representative light condensing method, and herein lamp 1 is placed at the first focal point of elliptical reflecting mirrors 2, and the light rays are collected at once near the second focal point 3 of elliptical reflecting mirrors 2. Furthermore, the light rays are corrected to be nearly parallel light rays by input lens 4, which has a focal point positioned at substantially same place as second focal point 3, and said light rays then enter optical integrator 5. Optical integrator 5 is a device having a plurality of bundled rod-shaped lenses, which can be considered a fly-eye.

The main purpose of passing light rays through this optical integrator 5 is to boost illumination uniformity, while input

lens 4 serves the purpose of reducing vignetting in the light rays that pass through optical integrator 5 in order to boost light condensing efficiency. Light which emerges from optical integrator 5 is collected by output lens 6 and collimation lens 7 so that light rays from each small lens in optical integrator 5 may overlap on reticule 8. Light rays which are caused to be incident on optical integrator 5 have an intensity distribution that depends on location, but light emerging from the small lenses of optical integrator 5 substantially uniformly overlap, and as a result, the illumination intensity on reticule 8 is substantially uniform. Naturally, the more nearly uniform the intensity distribution of light incident on optical integrator 5, the more uniform the illumination intensity distribution of light outputted therefrom and overlapping on reticule 8. Aperture stop 9 is placed on the exit side of optical integrator 5 and determines the dimension on the exit side of optical integrator 5.

When a mercury lamp is used as lamp 1 and the light therefrom is collected by elliptical reflecting mirrors 2, the structure of the mercury lamp is such that the lamp extends vertically with electrodes at both ends, as shown in figure 2,

(TRANSLATOR'S NOTE: This should be figure 5, I think)

and consequently, it is impossible to extract light rays in the sideways direction from lamp 1. As shown in figure 5, there are cases where the intensity distribution of light entering the center portion of optical integrator 5 falls only when a convex lens is used as input lens 4. Thus, there are cases where the intensity distribution of the light entering optical integrator 5 is further made uniform by inserting a biconvex or a meniscus conical lens between input lens 4 and optical integrator 5.

Filter 10 is a filter which allows only light of wavelengths for which the optical system has corrected aberrations to pass through, while cold mirrors 11 and 12 serve the purpose of bending the optical path so as to reduce the height of the device while causing the long wavelength light rays

to pass through and be absorbed in the cooling-capable portion of lamp housing 13. Light rays which illuminate reticule 8 pass through projection optical system 14, so that the image of very fine patterns on reticule 8 are projected and exposed on the resist on wafer 15. A stop 16 exists in projection optical system 14 to determine the numerical aperture.

There are numerous types of configurations for conventional projection exposure devices other than that shown in figure 5,

but schematically, a light source 17, first condensing optical system 18, homogenizing optical system 19, second condensing optical system 20, reticule 8, projection optical system 14 and wafer 15 are arranged in order, as shown in figure 6.

The first condensing optical system 18 is a portion that corresponds to elliptical reflecting mirrors 2 and input lens 4 in the example shown in figure 5, and consists of spherical mirrors, planar mirrors and lenses and the like in addition to elliptical mirrors, said items suitably arranged so that light rays from the light source enter homogenizing optical system 19 with as great an efficiency as possible. In addition, homogenizing optical system 19 is a portion corresponding to optical integrator 5 in figure 2,

(TRANSLATOR's NOTE: Again, I think this should be figure 5)

and besides this, uses multi-plane prisms and optical fibers or the like.

Second condensing optical system 20 is a portion corresponding to output mirror lens 6 and collimation lens 7 in figure 5, and this system causes light rays output from homogenizing optical system 19 to overlap and in addition assures image plane telecentricity. Besides this, a filter corresponding to filter 10 in figure 5 is inserted at a location where the light rays are nearly parallel to the optical axis, and in addition, reflecting mirrors corresponding to cold mirrors 11 and 12 are inserted, although the location of such is not critical.

In a device having this type of configuration, the properties of light when viewed from the reticule 8 toward the side which light is coming from are the properties of light which passes through second condensing optical system 20 with emerging from homogenizing optical system 19, so that the exit side of the homogenizing optical system 19 appears to be a light source. Consequently, in the case of the above-described configuration, the exit side 24 of the homogenizing optical system 19 is generally called the secondary light source.

When reticule 8 is projected onto wafer 15, the characteristics of formation of the projected and exposed pattern, that is to say the resolution and depth of focus, are determined by the numerical aperture of projection optical system 14 and the properties of light which illuminates reticule 8, that is to say, the properties of secondary light source 24. Figure 7 is an explanatory diagram relating to reticule-illuminating light rays and image-forming light rays in the projection and exposure device shown in figure 6.

In figure 7, projection optical system 14 normally has aperture stop 16 inside, and restricts the angle Θa of passage of light which has passed through reticule 8 while also determining angle Θ of light rays which fall on wafer 15.

In general, that which is called the numerical aperture NA of the projection optical system is the angle determined by NA = $\sin \Theta$, and has the relationship $\sin \Theta a = (\sin \Theta)/m$, where $1/m$ is the projection magnification. In addition, in this type of device, it is normal to have "image plane telecentricity", that is to say, to have a configuration such that principal light rays falling on the image plane are perpendicular to the image plane, and in order to satisfy the conditions of this "image plane telecentricity", the real image of the exit surface of homogenizing optical system 19 in figure 6, that is to say of the light source surface of secondary light source 24, is caused to be formed at the position of aperture stop 16. Under these conditions, when the angle formed when the secondary light source plane was observed through second condensing optical system from reticule 8 is interpreted as the range of light incident on reticule 8, and when the coherency σ of the illuminating light is defined to be $\sigma = \sin \phi / \sin \Theta a$, where ϕ is half of the above-described angle, the pattern formation characteristics have traditionally been considered to be determined by NA and σ. Hereinafter, a detailed description of the relationship between NA and σ and the pattern formation characteristics is provided. The resolution increases the larger NA is, but the depth of focus becomes shallow and in addition it becomes difficult to guarantee a wide exposure range because of aberrations in projection optical system 14. When a certain degree of exposure range and depth of focus (e.g., 10 mm angle, ± 1 μm) do not exist, the device cannot be used for applications to actual LSI production and the like, and consequently, there is a limit of around NA = 0.35 in conventional devices. On the other hand, the value of σ is related primarily to the pattern cross-sectional shape and depth of focus, and is related to the resolution with co-relation to the cross-sectional shape. Because the edge of the pattern is accentuated when the value of σ becomes small, the cross-sectional shape becomes a good pattern shape with the side walls nearly perpendicular, but in fine patterns, resolution worsens and the focus range where resolution is obtained narrows. Conversely, when the value of σ is large, the resolution and focal point range where resolution is obtained become somewhat good in fine patterns, but the inclination of the side walls in the pattern cross-section eases, and in the case of thick resist, the cross-sectional shape becomes trapezoidal or triangular. Consequently, with conventional projection and exposure optical devices, the value of σ that provides a relative balance is set at $\sigma = 0.5$ to 0.7, and experimentally, no conditions are tested other than conditions such as $\sigma = 0.3$ or

the like. In order to set the value of σ, it is preferable to determine the size of the light source plane of secondary light source 24, and consequently, a circular aperture stop 9 is generally positioned immediately behind the light source plane of secondary light source 24 in order to set the value of σ.

[Problems overcome by this invention]

In this kind of conventional device, only the value of the coherency σ controlled the properties of the light that illuminates reticule 8, and consequently, when the attempt was made to form a very fine pattern while satisfying various conditions for depth of focus, uniformity within regions and control of line width, there was a limit determined by NA and σ. Accordingly, when the numerical aperture NA of projection optical system 14 and the size of secondary light source 24 were determined, the pattern formation characteristics were automatically determined, and furthermore, it became impossible to increase the resolution performance.

In consideration of the foregoing, it is an object of the present invention to provide a projection exposure device which further improves pattern resolution performance after the numerical aperture of the projection optical system and the size of the secondary light source used in reticule illumination have been set.

[Problem solving means]

In order to achieve the above and other objects, the present invention uses a special stop having an annular passing area or the like, so that the transmissivity of the periphery is higher than that of the center, said stop used in place of circular stops used in conventional devices to determine the size of the secondary light source.

[Operation]

In the present invention, exposure is conducted only with light at the periphery of the secondary light source while light at the center of the secondary light source is not used when the resist is thin, in order to improve resolution.

[Preferred Embodiment]

Figures 1 to 4 show the preferred embodiments of the stop used to control the secondary light source, as special stops which can be applied to the projection and exposure device of the present invention.

The stop shown in figure 1 is a stop having an annular passing

area, and this stop can be composed of a light-blocking material such as chrome or the like vaporized onto a substrate with high transmissivity of illuminating light, such as quartz, calcium fluoride, lithium fluoride or the like. In addition, the stop in figure 2a is a stop having a distribution of transmissivity. This distribution of transmissivity makes the stop such that the transmissivity becomes larger closer to the perimeter, while the transmissivity is low or light is completely blocked near the center, as shown in figure 2b. Like the stop shown in figure 1, this stop can be made by attaching a light-blocking material onto a transmissive substrate so as to have a distribution of thickness in the radial direction. This can be of any type as long as the curve shown in figure 2b is a curve wherein the transmissivity becomes larger closer to the perimeter of the circle. The stop shown in figure 3 is a stop which has several or a plurality of small openings only at the periphery, and this stop can be made by making holes in a metal plate or the like. In addition, the stop in figure 4 is a stop similar to the stop shown in figure 1 which is created simply by cutting pieces out of a metal plate or the like, with connecting areas in portions of the circular aperture.

The configuration of the present invention may be the same as the configuration of a conventional device as shown in figure 5 or figure 6, with one of the stops shown in figures 1 to 4 mounted in place of aperture stop 9.

When the size of aperture stop 9 is changed, the side walls of the pattern obtained become more perpendicular the smaller the aperture, that is to say, the smaller the σ value. On the other hand, when the resolution of a fine pattern is considered, conversely adjacent patterns are separated from each other and transcribed, up to fine patterns, the larger the σ value. When the type of resist and the thickness of the film are determined from these two tendencies, i.e. the tendency for the cross-sectional shape to be better the smaller the σ value and the tendency for the resolution up to a fine pattern to be possible the larger the σ value, there is a suitable σ value by which the finest pattern can be formed within the range of cross-sectional shapes that can be used. Furthermore, when resist layers that are to be exposed are made thinner in consideration of using multiple layered resist, differences in the cross-sectional shape of the patterns are not very noticeable, and only the resolution becomes a problem. Consequently, the aforementioned suitable σ value moves toward the larger side.

Because the above-described relationship exists between the pattern resolution and the illuminating light, up to fine patterns can be resolved the more light toward the outside of the secondary light source is used when the resist layer is thin. Accordingly, going one step farther, if only the light at the periphery of the secondary light source is used, said light being necessary to resolve up to a fine pattern, the resolution can be made even higher.

With the projection and exposure device according to the present invention, said device using one of the stops shown in figures 1 to 4, it is possible to conduct exposure using only light from the periphery of the secondary light source without using light from the center of the secondary light source, and consequently, if the resist is made thinner, it is possible to obtain a very fine crystal pattern which cannot be obtained with a conventional device. For example, when a pattern is formed using an i-line of wavelength 365 nm, a projection magnification of 1/10, a numerical aperture of 0.35 in projection optical system 14, a resist OFPR of 800 and a thickness of 0.5 μm, with the first embodiment of a projection exposure device of the present invention using the annular aperture stop shown in figure 1, it was verified that a resolution could be obtained up to a line and space pitch of 0.8 μm and a line width of 0.4 μm, whereas a resolution could only be obtained up to a line and space pitch 1 μm and line width of 0.5 μm with a conventional circular aperture stop of $\sigma = 0.5$ as device conditions. The more outer peripheral light rays only are used in case where an annular stop is adopted, the higher resolution is attained, so though the effect varies depending on the outer shape. (TRANSLATOR's NOTE: This should be outer diameter, I think) as well as inner diameter of the annular aperture stop, in either of the cases higher resolution is provided than in case where a simple circular aperture is adopted. In addition, even when the stops shown in figures 2 to 4 are used, results will be created in accordance with the distribution of transmissivity of light in each, and in fact any shape besides these can be used which has a high transmissivity toward the outside.

Furthermore, with the present invention, it has been verified that the depth of focus deepens while the resolution increases. For example, in the case of the above-described resist pattern, the depth of focus becomes no less than ±0.5 μm in the case of a 0.4 μm line and space, and not less than ±1 μm in the case of 0.5 μm line and space. In conventional devices, this was around ±0.5 μm even with a 0.5 μm line and space, so that substantial improvement can been realized.

It is also possible to fix the position of this kind of special stop in the device, but because it is beneficial to

use the light near the center of the secondary light source when the resist film is thick, as noted above, it is beneficial for the special stop and a uniform stop such as a conventional circular aperture stop to be interchangeable.

In addition, if the device is configured as shown in Figure 5, and if a conical lens can be inserted/removed to thereby make distribution of light entering the optical integrator 5 changeable over between a periphery annular shape and a central concentration shape by inserting/removing the conical lens so that a distinction may be made between when to use a uniform stop such as a conventional circular stop and when to use the special stop, it is possible to use either stop properly without deteriorating the use efficiency of light rays. Furthermore, the light condensing efficiency can be improved even if the focal length and placement position are changed by making input lens 4 exchangeable so that the size of light rays entering optical integrator 5 can be changed. Referring to figure 5, in general the present invention can be made even more effective, when a special stop is used, by condensing light rays in a shape similar to the shape of the passing area of the special stop with using first condensing optical system 18 and by causing these light rays to enter homogenizing optical system 19 when a special stop is used.

[Efficacy of the Invention]

As described above, the present invention uses a special stop having an annular passing area, or the like, so that the transmissivity of the periphery is higher than that of the center, said stop used in place of circular stops used in conventional devices to determine the size of the secondary light source, and through this it is possible to form finer patterns with deeper depth of focus on thin resist layers than is conventionally possible. Consequently, if the present invention is applied to production of semiconductor integrated circuits or the like, it is possible to realize a large improvement in the degree of integration. In addition, because the present invention allows this kind of special stop to be interchanged with conventional uniform stops, the effect is that the present invention can also be used with resist having thick film.

4. Brief Description of the Drawings

Figures 1 to 4 are planar diagrams showing stops used to control the secondary light source as special stops that can be applied to the projection and exposure device of the present invention, figure 5 is a drawing of the configuration of a representative type of conventional projection and exposure device, figure 6 is a schematic drawing of the size thereof, and figure 7 is an explanatory drawing relating to reticule-illuminating light rays and image-forming light rays

therein.

1 lamp
2 elliptical reflecting mirrors
3 second focus
4 input lens
5 optical integrator
6 output lens
7 collimation lens
8 reticule
9, 16 aperture stops
10 filter
11, 12 cold mirrors
13 lamp housing
14 projection optical system
15 wafer
17 light source
18 first condensing optical system
19 homogenizing optical system
20 second condensing optical system
24 secondary light source

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Drawings:

Fig. 1

Fig. 2a, 2b

transmissivity

Fig. 3
Fig. 4
Fig. 5

Fig. 6

17 Light source
18 First condensing optical system
19 homogenizing optical system
20 second condensing optical system
14 projection optical system

Fig. 7

(54) PROJECTING AND EXPOSING DEVICE
(11) 61-91662 (A) (43) 9.5.1986 (19) JP
(21) Appl. No. 59-211269 (22) 11.10.1984
(71) NIPPON TELEGR & TELEPH CORP <NTT>(1)
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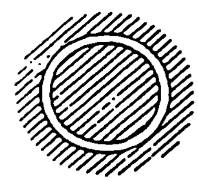
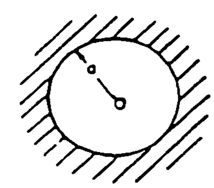


PURPOSE: To obtain higher resolution with a thin resist layer by mounting a special stop which has higher transmissivity at the center part than at the peripheral part instead of a uniform stop which determines the size of a secondary light source.

CONSTITUTION: When resist is thin, light from the center part of the secondary light source is not used so as to improve the resolution and only light from the peripheral part of the secondary light source is used for exposure. Consequently, the special stop is, for example, a stop having a annular passing area. In another way, a stop having a distribution of transmissivity is used instead thereof. Its transmissivity is so distributed that the transmissivity is higher toward the periphery and lowest or zero at the center. This special stop is only mounted instead of the aperture stop of the exit of an optical integrator. When a thin resist layer is used, the resolution is higher and higher as a pattern in use is thinner and thinner toward the outside of the secondary light source. For the purpose, only the light from the peripheral part of the secondary light source is used to obtain higher resolution.

(a)



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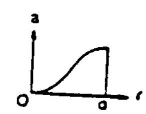

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⑫ 公開特許公報（A）　昭61－91662

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審査請求 未請求 発明の数 2 （全6頁）

㊹発明の名称　投影露光装置

㉑特　願　昭59－211269

㉒出　願　昭59(1984)10月11日

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明細書

1．発明の名称

投影露光装置

2．特許請求の範囲

(1) レチクル上のパターンを投影光学系を介してウエハ上に投影露光する投影露光装置において、前記レチクルを照明する2次光源の射出面内強度分布を周辺部強度が中央部強度より大とせしめる特殊絞りを有することを特徴とする投影露光装置。

(2) 特殊絞りは，2次光源面の直後に装着可能であり，開口形状，透過率分布を周辺部の光強度が中央部の光強度より大となるようになしたことを特徴とする特許請求の範囲第1項記載の投影露光装置。

(3) レチクル上のパターンを投影光学系を介してウエハ上に投影露光する投影露光装置において、前記レチクルを照明する2次光源の射出面内強度分布を周辺部強度が中央部強度より大とせしめる特殊絞りと2次光源の射出面内強度分布に影響を与えない均一絞りとを交換可能としたことを特徴とする投影露光装置。

(4) 特殊絞りと均一絞りとは，2次光源面の直後に装着可能であることを特徴とする特許請求の範囲第3項記載の投影露光装置。

(5) 2次光源は，その前面に，2次光源を形成するための均一化光学系に入射する光束の光強度分布を2次光源面の直後に入れる絞りの開口形状，透過率分布に近似させることを可能にする円錐レンズを有することを特徴とする特許請求の範囲第4項記載の投影露光装置。

3．発明の詳細な説明

〔産業上の利用分野〕

本発明は、半導体集積回路等の製造に要する微細レジストパターンを形成する投影露光装置に関するものである。

〔従来の技術〕

第5図に従来の投影露光装置を示す。第5図において、1はランプ、2は楕円反射鏡、3は楕円反射鏡2の第2焦点、4はインプットレンズ、5はオプチカルインテグレータ、6はアウトプット

レンズ、7はコリメーションレンズ、8はレチクル、9は均一絞りとしての開口絞り、10はフィルタ、11．12はコールドミラー、13はランプハウス、14はレンズまたはミラーあるいはその組み合わせによりレチクル8上のパターンの像をウエハ上に投影する投影光学系、15はウエハ、16は開口絞りである。

従来、この種の投影露光装置の多くは光源のランプ1として水銀灯を使用し、g線436nm．h線405nm．i線365nm等の輝線またはこれらの波長近辺の連続スペクトルを取り出して用いている。このため光源のランプ1は高い輝度が必要であるとともに集光効率や照射均一性を考えると点光源に近い方が良い。しかし、実際にはそのような理想的な光源は存在しないため、有限の大きさでしかも強度に分布を持つランプ1を使用せざるを得ず、そのようなランプ1から発せられる光をいかに高効率で、かつ、照射均一性の良い光に変換するかが課題となる。

第5図に示した装置は従来の代表的な集光方法を用いた構成の装置であり、楕円反射鏡2の第1焦点にランプ1を置き、楕円反射鏡2の第2焦点3付近に一旦光束を集める。そして、第2焦点3とほぼ焦点位置を共有するインプットレンズ4により光束をほぼ平行光束に直し、オプチカルインテグレータ5に入れる。オプチカルインテグレータ5は多数の棒状レンズを束ねたもので、はえの目レンズとも称される。このオプチカルインテグレータ5を通すことが照射均一性を高める主因となっており、インプットレンズ4はオプチカルインテグレータ5を通る光線のケラれを少なくして集光効率を高める役目をなす。このオプチカルインテグレータ5を出た光は、アウトプットレンズ6およびコリメーションレンズ7によって、オプチカルインテグレータ5の各小レンズから出た光束がレチクル8上に重畳して当たるよう集光せられる。オプチカルインテグレータ5に入射せらるる光線は場所による強度分布を有するが、オプチカルインテグレータ5の各小レンズから出る光がほぼ等しく重畳せらるる結果、レチクル8上では照射強度がほぼ均一となる。当然のことながらオプチカルインテグレータ5に入射する光の強度分布が均一に近ければ、出射光を重畳させたレチクル8の照度分布はより均一になる。オプチカルインテグレータ5の出射側には開口絞り9がおかれ、オプチカルインテグレータ5の出射側寸法を決めている。

ランプ1として水銀灯を用いて楕円反射鏡2で集光する場合、水銀灯の構造が第2図に示すように縦長であり両端が電極となっているため、ランプ1の軸方向の光線を取り出すことができない。そのため、第5図に示すように、インプットレンズ4として凸レンズを使用したのみではオプチカルインテグレータ5の中心部に入る光の強度分布が落ちる場合がある。そこで、インプットレンズ4とオプチカルインテグレータ5との間に両凸又は片凸片凹の円錐レンズを挿入し、オプチカルインテグレータ5に入る光の強度分布をより一様にする場合もある。

フィルタ10は、光学系が収差補正されている波長の光だけを通すためのものであり、コールドミラー11．12は光路を曲げて装置の高さを低くするとともに、長波長光熱線を透過させてランプハウス13の冷却可能部分に吸収させる役目を担う。レチクル8を照射した光は投影光学系14を通り、レチクル8上の微細パターンの像がウエハ15上のレジストに投影露光転写される。投影光学系14の中には開口数を決定する絞り16が存在する。

従来の投影露光装置の構成は第5図に示した以外にも多数あるが、模式的には第6図のごとく、光源17．第1集光光学系18．均一化光学系19．第2集光光学系20．レチクル8．投影光学系14．ウエハ15の順に配列されている。

第1集光光学系18は第5図の例で楕円反射鏡2およびインプットレンズ4に相当する部分であり、楕円鏡のほか球面鏡．平面鏡．レンズ等を適当に配置し、光源から出る光束をできるだけ効率よく均一化光学系19に入れる役目を持つ。また、均一化光学系19は第2図のオプチカルインテグ

レータ5に相当する部分であり、その他として光ファイバや多面体プリズム等が使用されることもある。

第2集光光学系20は第5図のアウトプットレンズ6およびコリメーションレンズ7とに相当する部分であり、均一化光学系19の出射光を重畳させ、また、像面テレセントリック性を確保する。この他、光束が光軸平行に近い個所に第5図のフィルタ10に相当するフィルタが挿入され、また、コールドミラー11，12に相当する反射鏡も、場所は一義的でないが、挿入される。

このように構成された装置においてレチクル8から光が来る側を見た場合、光の性質は、第2集光光学系20を通して均一化光学系19から出てくる光の性質となり、均一化光学系19の出射側が見掛け上の光源に見える。このため、上記のような構成の場合、一般に均一化光学系19の出射側24を2次光源と称している。

レチクル8がウエハ15上に投影せらるる時、投影露光パターンの形成特性、すなわち、解像度や焦点深度等は、投影光学系14の開口数およびレチクル8を照射する光の性状、すなわち、2次光源24の性状によって決まる。第7図は第6図に示した投影露光装置におけるレチクル照明光線・結像光線に関する説明図である。

第7図において、投影光学系14は通常内部に開口絞り16を有しており、レチクル8を通った光が通過し得る角度θaを規制するとともにウエハ15上に落射する光線の角度θを決めている。

一般に投影光学系の開口数NAと称しているのは、NA＝$\sin\theta$で定義される角度であり、投影倍率を1／mとすると、$\sin\theta a=\sin\theta/m$の関係にある。またこの種の装置においては、「像面テレセントリック」、すなわち、像面に落ちる主光線が像面に垂直に構成されるのが普通であり、この「像面テレセントリック」の条件を満たすため、第6図の均一化光学系19の出射面、すなわち、2次光源24の光源面の実像が開口絞り16の位置に結像せらるる。このような条件下でレチクル8から第2集光光学系を通して2次光源面を見た時の張る角をレチクル8に入射する光の範囲としてとらえ半角をϕとし照明光のコヒーレンシイσを$\sigma=\sin\phi/\sin\theta a$で定義した場合、パターン形成特性はNAと$\sigma$で決定せらるるものと従来考えていた。次にNAおよびσとパターン形成特性との関連について詳細に説明する。NAが大きい程解像度は上がるが、焦点深度が浅くなり、また、投影光学系14の収差のため広露光領域の確保が難しくなる。ある程度の露光領域と焦点深度（例えば10mm角，±1μm）がないと実際のLSI製造等の用途に使えないため、従来の装置ではNA＝0.35程度が限界となっている。一方、σ値は主としてパターン断面形状・焦点深度に関係し、断面形状と相関を持って解像度に関与する。σ値が小さくなるとパターンの淵が強調されるため、断面形状は側壁が垂直に近づいて良好なパターン形状となるが、細かいパターンでの解像性が悪くなり解像し得る焦点範囲が狭くなる。逆にσ値が大きいと細かいパターンでの解像性，解像し得る焦点範囲が若干良くなるが、パターン断面の側壁傾斜がゆるく、厚いレジストの場合、断面形状は台形ないし三角形となる。このため従来の投影露光装置では、比較的バランスのとれたσ値として、σ＝0.5～0.7に固定設定されており、実験的にσ＝0.3等の条件が試みられているにすぎない。σ値を設定するには2次光源24の光源面の大きさを決めれば良いため、一般に2次光源24の光源面の直後にσ値設定用の円形開口絞り9を置いている。

（発明が解決しようとする問題点）

このような従来の装置においては、レチクル8を照射する光の性質を制御するのがコヒーレンシイσ値だけであるため、焦点深度，領域内均一性・線幅制御性等各種条件を満たしつつ微細パターンを形成しようとすると、NAとσとによって決まる限界があった。したがって、投影光学系14の開口数NAと2次光源24の大きさが決まると、パターン形成特性が自動的に決り、さらに解像性能を高めることはできなかった。

本発明はこのような点に鑑みてなされたもので

あり、その目的とするところは、投影光学系の開口数とレチクル照射用２次光源の大きさを固定した後のパターン解像性能をさらに向上させる投影露光装置を提供することにある。

〔問題点を解決するための手段〕

このような目的を達成するために本発明は、従来装置が用いていた２次光源の大きさを決める円形絞りの代わりに円輪状透過部を有する形状等中央部に対して周辺部の透過率が高くなるようにした特殊絞りを装着可能としたものである。

〔作用〕

本発明においては、レジストが薄い場合、解像度向上のために２次光源の中心部の光を用いず２次光源の周辺部の光のみによって露光する。

〔実施例〕

本発明に係わる投影露光装置に適用される特殊絞りとしての２次光源制御用絞りの各実施例を第１図～第４図に示す。

第１図に示す絞りは円輪状に透過域を有する絞りであり、照射光の透過率が高い石英．フッ化カルシウム．フッ化リチウム等の基板にクロム等の遮光体を蒸着することによって作製することができる。また第２図(a)に示す絞りは透過率に分布を有する絞りである。この透過率の分布は、第２図(b)に示すように、周辺に近づく程透過率が高く中心に近づくと低透過率あるいは完全遮光となる絞りである。この絞りは、第１図に示す絞り同様に、透過基板に遮光体を径方向に厚さ分布を持たせて付着させることにより作製することができる。なお第２図(b)に示す曲線は、円の周辺に近づく程透過率が高くなる曲線であれば何でもよい。第３図に示す絞りは周辺部のみに数個又はそれ以上の多数個の小開口を有する絞りであり、金属板等に穴をあけることにより作製できる。また、第４図に示す絞りは第１図に示した絞りに近いものを簡便に金属板等をくりぬいて作製するため、円輪開口部の一部につなぎの部分を入れたものである。

本発明の構成は、第５図または第６図に示した従来装置の構成と同じでよく、開口絞り９の代わりに第１図～第４図に示した絞りを装着すればよい。

開口絞り９の大きさを変えた場合、開口が小さい程、すなわち、σ値が小さい程得られるパターンの側壁は垂直に近くなる。一方、細かいパターンでの解像性を調べると、逆に、σ値が大きい程細かいパターン迄隣接したパターンどうしが分かれて転写される。かかる２つの傾向、すなわち、σ値が小さい程断面形状が良くなる一方、σ値が大きい程細かいパターン迄解像できるという傾向からレジストの種類．膜厚を決めると、使用に耐える範囲の断面形状で最も細かいパターン迄ぬけるσ値の適値が存在する。そして、多層レジスト等の使用を考え露光すべきレジスト層を薄くする場合には、パターンの断面形状の差異はさほど顕著にならず解像性のみが問題となるので、上記のσ値の適値はσが大きい方に移行する。

照明光とパターン解像性との間に上記のごとき関係があるから、薄いレジスト層の場合には、２次光源の外側迄使う程細かいパターン迄解像する。したがって、さらに一歩進めて、細かいパターン迄解像するために必要な２次光源の周辺部の光だけを用いれば、一層の高解像度化がはかれる。

第１図～第４図に示した絞りを用いた本発明に係わる投影露光装置では、２次光源の中心部の光を用いず２次光源の周辺の光のみによって露光することができるので、レジストを薄くすれば、従来の装置ではとうてい得られなかった微細結晶のパターンを得ることができる。例えば、波長３６５ｎｍのｉ線を用い、投影倍率１／１０，投影光学系１４の開口数0.35，レジストＯＦＰＲ８００．０.５μｍ厚でパターン形成を行なうと、従来の円形開口絞りでσ＝０.５とした装置条件では、線幅０.５μｍ，ピッチ１μｍのラインアンドスペースまでしか解像し得ないが、第１図に示した円輪状開口絞りを使用した本発明の投影露光装置の一実施例によれば、線幅０.４μｍ，ピッチ０.８μｍのラインアンドスペースまで解像し得ることが確認されている。円輪状開口絞りにおいてはできるだけ外側の光線だけを使うようにする程高解像性となるので、円輪開口絞りの外形．内径により効

果はおのおの異なってくるが、いずれの場合も単純な円形開口に比較すると高解像となる。また、第2図～第4図に示した絞りを用いてもそれぞれ透過光の分布に応じた効果を生じ、これら以外の形状でも外側で高透過性を有する形状ならば何でもよい。

さらに本発明によれば、解像性が上がるとともに焦点深度が深くなることが確認されている。例えば、上記レジストパターンの場合、0.4μmラインアンドスペースで±0.5μm以上、0.5μmラインアンドスペースで±1μm以上の焦点深度となる。従来は0.5μmラインアンドスペースでも±0.5μm程度であり、かなりの改善がはかれる。

このような特殊絞りを装置に固定設置することも可能であるが、前述のようにレジスト膜厚が厚い場合には、2次光源の中心部付近を使用した方が有利になることもあるので、従来の円形開口絞り等の均一絞りと特殊絞りを交換可能としておけばより便利である。

また、装置を第5図のごとく構成し、オプチカルインテグレータ5の前に円錐レンズを着脱可能とし、オプチカルインテグレータ5に入る光の分布を円錐レンズの着脱により周辺円輪状と中央集中型とに切換え可能とし、従来の円形絞り等の均一絞り使用時と特殊絞り使用時とで使い分けられるようにすれば、光線の使用効率を落とさずに使い分けができる。さらにインプットレンズ4を交換できるようにして焦点距離，設置位置を変え、オプチカルインテグレータ5に入る光束の大きさを変えられるようにしても集光効率を改善できる。第5図に基づき一般的に言うと、特殊絞り使用時に特殊絞りの透過部分形状に類似した形状の光束に第1集光光学系18により集光し、この光束を均一化光学系19に入れるようにすれば、本発明はより有効である。

〔発明の効果〕

以上説明したように本発明は、従来装置が用いていた2次光源の大きさを決める円形絞り等の均一絞りの代わりに円輪状透過部を有する形状等中央部に対して周辺部の透過率が高くなるようにした特殊絞りを装着することにより、厚いレジスト層に従来より微細なパターンをより深い焦点深度で形成することができるので、半導体集積回路等の製造に適用すれば大幅な集積度向上がはかれる効果がある。また本発明はこのような特殊絞りと従来の均一絞りとを交換可能としたので、膜厚の厚いレジストにも対応できる効果がある。

4．図面の簡単な説明

第1図～第4図は本発明に係わる投影露光装置に適用される特殊絞りとしての2次光源制御用絞りを示す平面図、第5図は従来の代表的な投影露光装置を示す構成図、第6図はその模式的構成図、第7図はそのレチクル照明光線，結像光線に関する説明図である。

1・・・・ランプ、2・・・・楕円反射鏡、3・・・・第2焦点、4・・・・インプットレンズ、5・・・・オプチカルインテグレータ、6・・・・アウトプットレンズ、7・・・・コリメーションレンズ、8・・・・レチクル、9，16・・・・開口絞り、10・・・・フィルタ、11，12・・・・コールドミラー、13・・・・ランプハウス、14・・・・投影光学系、15・・・・ウエハ、17・・・・光源、18・・・・第1集光光学系、19・・・・均一化光学系、20・・・・第2集光光学系、24・・・・2次光源。

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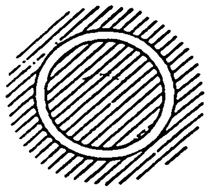
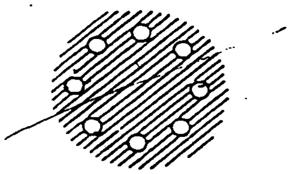
代理人　山川政樹（ほか1名）

第1図



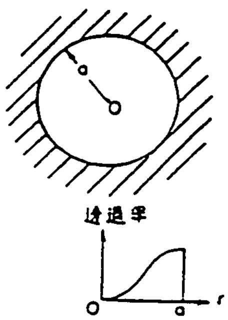
第3図



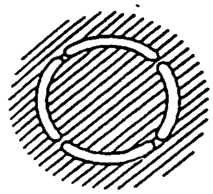
第2図

(a)

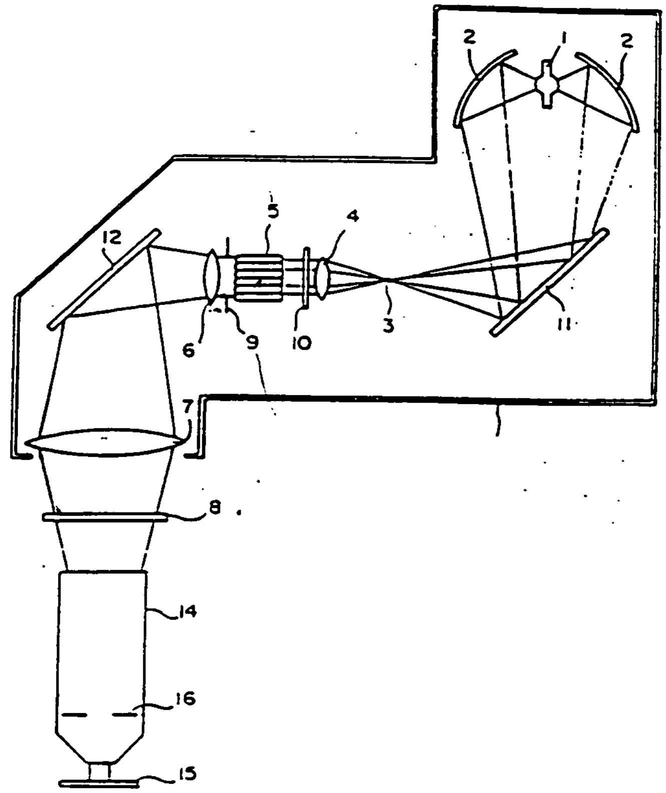
(b)



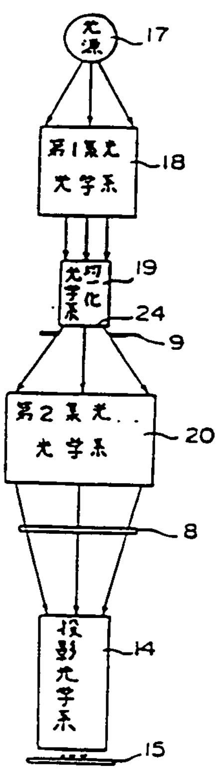
第4図



第5図



第6図



第7図